**Fascinating Education Script**
**Introduction to Science Lessons**

# Lesson 3: Candle

## Slide 1: Introduction

## Slide 2: Who is Michael Faraday?

Over 150 years ago, Michael Faraday gave a series of lectures to the public about something as simple as a candle. Faraday was a master of observation. He looked at things carefully and always asked why.

Here is some of what he talked about.

## Slide 3: Studying a candle flame

You just looked at the candle flame. What did you see? Tell me everything you saw about the candle flame?

Did you see the candle wick inside the flame? What was the color of the wick? What was the color of the flame?

Was it the same color throughout the flame?

Did you see anything above the candle flame?

## Slide 4: Why do candle flames have different colors?

Here are two candle flames. Take a few minutes and write down all the ways that they look alike?

Let’s begin at the bottom. The candle is solid but both wicks are sitting in a liquid where the candle has melted. Between the liquid and the flame is an area without a flame. Right where the wicks enter the flame, the wicks become black.

Right above the wick, both flames become dark red or dark orange, and right above that the flames turn yellow.
Above the yellow is the bright white part of the flame.

And above the white part is another yellow layer, and maybe even a dark red layer above that.

What do all these parts mean?

## Slide 5: What are candles made of?

Let's begin with the candle itself. Candles are made out of wax. A wax is like liquid oil except that it's solid at room temperature.

Take some olive oil or corn oil from the kitchen and place in the freezer. In a few hours it will come out feeling like a wax. The only difference between a wax and an oil, is that at room temperature, oil is liquid, and wax is solid.


Wax and fat are similar in that both feel greasy and both melt when you heat them.

Oils come from the seeds of fruits and vegetables. Oils have lots of energy in them, so they are used by seeds when they are first opening up, before sunlight has had a chance to shine on them.

## Slide 6: What color are oils and waxes?

Oils and waxes are generally colorless or perhaps light yellow, unless of course you color them with food coloring or some other dye.

Even though oils and waxes have only a little color, the main thing that makes up oils and waxes is carbon. Coal is practically pure carbon.

How is possible for black carbon to be the main ingredient of oils and waxes if oils and waxes aren't black?

## Slide 7: What happens when you attach one chemical to another?

Because the carbon that's present in oils and waxes is not present as tiny bits of carbon. Tiny bits of carbon are called "soot." There's no soot in your butter, because the carbon in your butter is chemically attached to another chemical: hydrogen. This is the amazing thing about chemistry. When you attach one chemical to another, the new chemical doesn't look anything like either of the two chemicals you started out with.

## Slide 8: What does the heat of a candle flame do?

Look at the burning candle again. Do you see anything that looks like soot?

Do you see the black bits of soot hanging onto the wick? The heat of the flame is releasing the carbon in candle wax and allowing the carbon to collect on the wick.

The same thing happens when you roast a marshmallow.

Do you see the soot anywhere else in the candle flame?

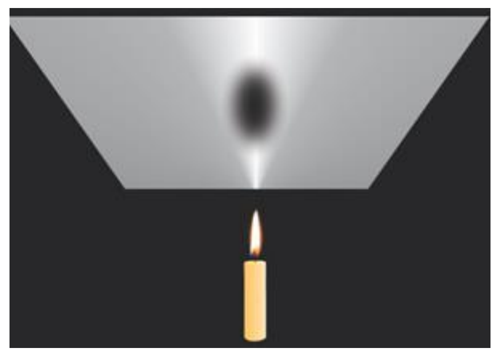
## Slide 9: Heat is energy.

That whole bright white part of the flame is soot, glowing soot. Heat is energy and all that energy in the heat of the flame is causing tiny particles of soot to glow, just like a rod of steel in a blacksmith's furnace glows white hot.

We can capture some that soot by holding a piece of metal over the flame. The large black spot is soot. Feel the soot with your fingers. What does it feel like?

Kind of greasy isn't it? What use could you make of greasy soot?

How about to loosen up locks jammed with rust. It's called graphite but chemically it's a close cousin of greasy carbon soot.

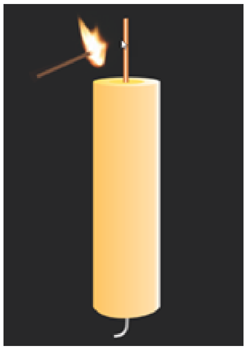
## Slide 10: What does the wick do?

The wick of a candle sits in a puddle of liquid candle wax. Why do you need a wick?

Yes. To draw up the liquid wax. How does the wick do that?

The same way a mop soaks up water on the floor. Water creeping up a mop or a paper towel is called capillary action.


Does a candle wick have to be made of something absorbent like cotton?



Turn the candle over and jam a wire into the bottom of the candle. Light the wire, or even melt the candle around the base of the wire. No candle flame. So the answer seems to be yes, you need something absorbent for capillary action to take place.

## Slide 11: Can a celery stick be a wick?

If I place this celery stick in this colored water, capillary action allows the colored water to climb up the celery stick.

Let's see if a celery stick can serve as a wick.

Lookee here! The celery stick allows the oil in this plate to creep up to the top of the celery stack and be burned.

## Slide 12: Why do you need a wick?

Why do you need a wick at all? Why can't you just light the candle wax itself? In fact, when you light the wick, why doesn't the flame proceed down the wick right into the candle and cause the whole candle to burn?

Because a solid candle will never burn, even if you hold a flame right under a candle. Even if we melt the candle, sticking a lighted match into a melted puddle of candle wax will not cause the liquid wax to ignite.

## Slide 13: Why won't liquid wax catch fire?

Why won't liquid wax or liquid gasoline catch fire, and what does the wick do to allow the liquid wax to catch fire?

We know that it takes a lighted match to light a candle. The wick then carries liquid candle wax upward into the wick. What happens in the wick that allows the liquid wax to be ignited?

Give me a hypothesis. It doesn't have to be right. It just has to be testable.

How about this for a hypothesis? Liquids cannot burn. Liquids have to evaporate into the air as a gas in order to catch fire. When the liquid wax climbs the wick through capillary action, the heat of the flame evaporates the liquid wax into the air where the wax mixes with oxygen and catches fire.

First, what is a gas?

A gas is anything that mixes invisibly with air. Gases are invisible; you cannot see a gas. If you can see it, it's not a gas; it's a "vapor." For example, here is a steam iron putting out steam.

Where the steam first comes out, it's invisible until the steam cools and forms tiny water droplets, called ……. water vapor.

Now, how do we test our hypothesis that liquid wax is evaporating into the air and catching fire?
This hypothesis says that gases when mixed with air can ignite. Maybe not all gases, but at least some gases. Is there any evidence for that?

## Slide 14: How can we design an experiment?

Sure. Gas stoves, gas water heaters, and gas furnaces all burn natural gas.
Okay, but that doesn't prove that candle wax is evaporating into the air to be ignited into a flame.

What kind of experiment could we do to show that candle wax is evaporating from a lit candle wick?

## Slide 15: Let's explore other explanations.

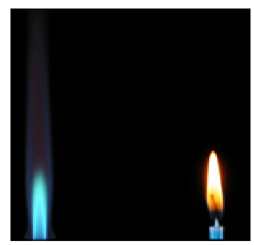
Of course. Pinch off the flame and see if we can relight the candle by holding a lighted match above the wick. Here is a lighted match doing just that.

Does that prove that wax was evaporating from the wick?

No, because there could be other reasons for the candle to relight that have nothing to do with candle wax evaporating into the air.

Let's see if we can find another reason for the candle to relight after we snuffed it out.

## Slide 16: Why is a candle flame yellow and white, while a natural gas flame is blue?

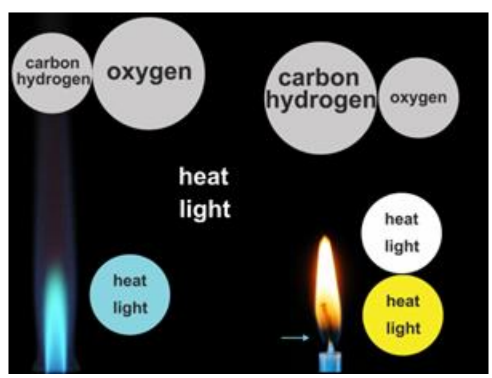


What is the main difference you see between the kitchen stove flame and the candle flame?

Right. The color. The stove flame burns natural gas as a blue color, while the candle flame is yellow and white.

Why is a candle flame yellow and white, while a natural gas flame is blue?

To answer that, we need to understand what fire is. What is fire?




Fire is heat and light. The heat and light are two forms of energy that are released when certain chemicals suddenly combine with oxygen. In the case of natural gas and candle wax, the chemicals are carbon and hydrogen chemically connected to each other.

When natural gas burns, there is plenty of oxygen around and all the carbon and hydrogen are able to completely combine with oxygen to form a nice blue flame, which is very hot.

When a candle burns, the only place where there is enough oxygen is at the bottom of the flame. See the blue part of the flame at the bottom?

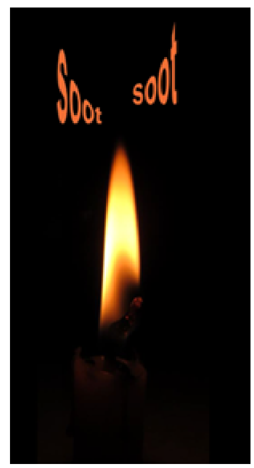
In the rest of the candle flame, there isn't enough oxygen to combine with all the carbon and hydrogen. Whatever carbon and hydrogen are left over form soot. When soot is heated, it glows yellow, and if the flame is hot enough, it turns white hot.

## Slide 17: Why does the flame turn from white to yellow and orange at the top?

Right above the white part of the candle flame is a cap of yellow and orange. Why does the flame turn from white to yellow and orange at the top?

It has to do with why the candle flame points upward. Why does the candle flame point upward?

Hot air rises and cold air sinks, because cold air is heavier than hot air.

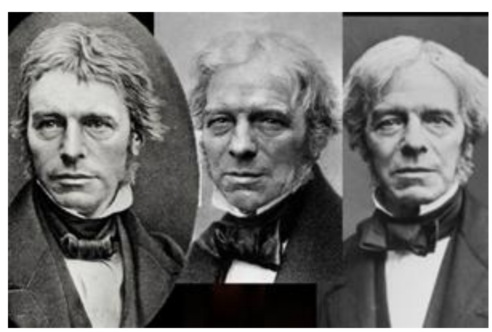



As the hot air inside a candle flame rises, the top of the flame becomes cooler. Why?

Because the top of the flame is further from the wick where all the gas is evaporating and igniting.

As the flame loses heat, it can no longer heat the carbon soot particles white hot, and we begin to see the yellow flame again containing the cooler burning soot.

We now have another reason to explain how we were able to relight the candle wick. Right above the wick is unburned soot being carried upward by the hot air. A lighted match can relight that soot.



There is so much more that Faraday talked about in his public lectures about candles. I hope what I have covered has encouraged you to be more observant of what's around you and to ask why things happen, even it seems obvious why they happen.